

FINAL PROGRAM



Sponsored by the
Transducer Research Foundation, Inc.



Program at a Glance

| JUNE 8 SUNDAY | JUNE 9 MONDAY | JUNE 10 TUESDAY | JUNE 11 WEDNESDAY | JUNE 12 THURSDAY |
|---|--|---|--|--|
| | Breakfast 7:00 am | | | |
| | Welcome 7:45 am | Breakfast 7:30 am | Breakfast 7:30 am | Breakfast 7:30 am |
| | Plenary Speaker I 8:15 am - 9:05 am Oliver Paul <i>University of Freiburg - IMTEK, GERMANY</i> | Plenary Speaker II 8:15 am - 9:05 am Robert Carpick <i>University of Pennsylvania</i> | Plenary Speaker III 8:15 am - 9:05 am Kurt Petersen <i>Band of Angels</i> | Session 8 Late News Papers Oral 8:15 am - 9:45 am |
| Optional Sunday Workshop Frontiers of Characterization and Metrology for Micro- and Nanosystems 9:00 am - 4:30 pm | Session 1 Biomedical & Cellular Devices 9:05 am - 10:05 am | Session 3 Materials & Surfaces 9:05 am - 9:45 am | Session 6 High-Q Resonators 9:05 am - 10:25 am | Break 9:45 am - 10:10 am |
| | Break 10:05 am - 10:30 am | Break 9:45 am - 10:10 am | | Session 9 Lab Chip & Microfluidics 10:10 am - 11:30 am |
| | Session 2 Bioassays 10:30 am - 11:30 am | Session 4 Fabrication & Materials 10:10 am - 11:10 am | Break 10:25 am - 10:50 am | |
| | Poster Preview Session 1 11:30 am - 12:15 pm | Session 5 Magnetic Transducers 11:10 am - 12:10 pm | Session 7 Resonant Systems 10:50 am - 12:10 pm | Networking Lunch 11:30 am - 1:00 pm |
| | | | Poster Preview Session 2 12:10 pm - 12:55 pm | |
| | Networking Lunch 12:15 pm - 1:45 pm | Networking Lunch 12:10 pm - 1:40 pm | | |
| | Poster Session 1 - Contributed and Late News 1:45 pm - 4:45 pm | Golf and Volleyball Tournaments | Networking Lunch 12:55 pm - 2:25 pm | |
| | | | Poster Session 2 - Contributed and Late News 2:25 pm - 5:25 pm | |
| | | | | |
| | | | | |
| | | | | |
| | | | Reception and Poster Session 3 - Commercial & Open Posters 6:30 pm - 8:00 pm | |
| Registration & Welcome Reception 6:00 pm - 9:00 pm | | Banquet 7:00 pm - 10:00 pm | Rump Session 8:00 pm - 10:30 pm | |
| | | | | |

General Information

Meeting Room Logistics

Please contact the Workshop Registration Desk if you find the temperature in the room uncomfortable or you are unable to hear or see because of equipment difficulties.

Information/Message Board

The Information/Message Board will be located near the Workshop Registration Desk. Messages will be posted in this area throughout the Workshop.

Job Market Board

Please visit the Job Market Board also located near the Workshop Registration Desk to see current job opportunities or to place your resume on the board.

Name Badges

All attendees and their guests must wear their name badges to all sessions and social functions.

Smoking

All meeting rooms and seated functions are smoke free. Please regard the smoking policy of the Sonesta Resort and use designated smoking areas only.

Cellular Phones, Beepers, and Watch Alarms

Out of courtesy to our speakers and other attendees, please turn off any cellular phones, pagers and watch alarms during sessions.

Wireless Internet Service

Wireless Internet will be available in the Workshop meeting space in the Sonesta Resort.

- Select "SSAMW" from the list of available networks.
- Once prompted, the Workshop code is: **HiltonHead** (case sensitive)

We ask that you limit your usage to be considerate of other attendees and please logout once you are finished. There is a bandwidth limit of 2 Mbps per device.

Guest Packages

Guest meal packages are available for purchase for all guests of attendees. The package includes the Sunday Welcome Reception, Guest Breakfast (Santee Ballroom 7:30 a.m. – 10:00 a.m.), Lunches, and the Tuesday Banquet. Please visit the Workshop Registration Desk if you would like to purchase a guest package.

Adult guest packages may be purchased for \$225.00 and Child packages (7 - 12 years of age) are available for \$125.00. Children under 6 are free.

Guests and children will not be admitted to social events without a badge. A name badge is required for anyone to attend the meal functions. Children under 6 are free, but will still require a name badge, so please register them as well if you have not already done so. Access will not be permitted without a name badge.

Workshop Social Events

Name badges are required for all Social Events, including guests.

Sunday Welcome Reception

The Welcome Reception will be held Sunday evening, June 8th, 6:00 p.m. - 9:00 p.m. outside in the Pavilion and is sponsored in part by Knowles.

Tuesday Banquet

The Tuesday Banquet will be held on Tuesday, June 10th, 7:00 p.m. - 10:00 p.m. outside in the Pavilion and is sponsored in part by Freescale.

Women in MEMS Breakfast

The Women in MEMS Breakfast will be on Tuesday from 7:15 a.m. - 8:10 a.m. in the Jasper Room, 2nd Floor. Ladies, grab your breakfast and coffee from the Workshop Breakfast Area and join us. Come meet new faces, catch up with old friends, and make connections. Students and first-time attendees are especially encouraged to attend and join the Women in MEMS Network.

Golf Tournament

Tuesday afternoon provides for an open agenda. Why not join the adventuresome and "T" it up at the Annual Hilton Head Workshop Golf Tournament which is sponsored again by Kaplan Breyer Schwartz & Ottesen, LLP. This event is open to all that enjoy the peaceful serenity of lush fairways and manicured greens. The ability to play 9 or 18 holes is also available. You can sign up as a single, pair, threesome or gather a foursome. A summary of the outing, including presentation of awards will be announced at the Rump Session on Wednesday. If you are interested in joining the Golf Tournament, sign up at the Workshop Registration Desk.

Beach Volleyball

The Beach Volleyball, sponsored by Coventor, will be held on Tuesday afternoon between 2:00 p.m. and 5:30 p.m. All levels of play will be integrated into this fun afternoon. If you are interested in joining the Beach Volleyball, please head out to the beach area at the Resort after 2:00 p.m. Coventor will be supplying refreshing drinks and snacks, so come out and play, or just come watch the fun.

Organizing Committee

| | |
|--|---|
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| | |
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| Xiao-An “Sean” Fu | <i>University of Louisville</i> |
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| Florian Herrault | <i>HRL Laboratories</i> |
| David Horsley | <i>University of California, Davis</i> |
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| George Skidmore | <i>DRS Technologies</i> |
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Transducer Research Foundation

The Transducer Research Foundation (TRF) is a nonprofit organization whose mission is to stimulate research within the United States in science and engineering, with emphasis on technologies related to transducers, microsystems, and nanosystems, and to foster the exchange of ideas and information between academic, industrial, and government researchers. The founders of TRF were also the founders of this biennial "Workshop on Solid-State Sensors, Actuators, and Microsystems," which began in 1984 under IEEE sponsorship. TRF took over the full sponsorship of the Workshop in 1994. TRF also sponsors other topical Workshops in the microsystems field and supports student development through travel grants that enable students to attend major microsystems Conferences and Workshops worldwide.



If your organization would like to explore any of these options for TRF sponsorship or student grants, please contact someone at the Workshop Registration Desk, or a TRF officer/board member, or visit the web-site www.transducer-research-foundation.org for further information.

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Acknowledgement

TRF would like to thank NIST, iNEMI and MEMS Industry Group for sponsoring the Sunday Frontiers of Characterization and Metrology for Micro- and Nanosystems Workshop. A special thank you to Michael Gaitan, Jason Gorman, and Richard Allen from NIST for developing and conducting the Workshop.



Commercial Support

Special acknowledgement to the Transducer Research Foundation, Inc. and the Analog Devices for their educational grant funding support of this Workshop.



<http://www.transducer-research-foundation.org>

The Transducer Research Foundation, Inc. would also like to thank the following companies for their support, encouragement, and involvement in the 2014 Solid State Sensors, Actuators and Microsystems Workshop.

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Berkeley Sensor & Actuator Center (BSAC), founded 1986, is the NSF Industry/University Cooperative Research Center for MEMS with 35 member companies and 150 researchers.

MEDIA CONTRIBUTORS

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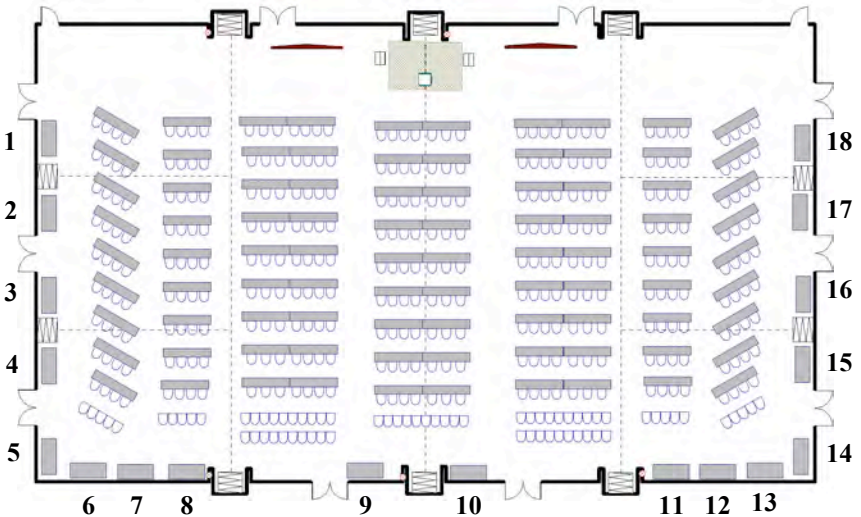
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Tabletop Floorplan

Santee Ballroom



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| memsstar Ltd..... | 5 |
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Sunday, June 8

- 6:00 p.m. - **Registration and Welcome Reception**
9:00 p.m. *Welcome Reception sponsored in part by Knowles*

Monday, June 9

- 7:00 am **Breakfast**

- 7:45 am **Welcome**
Mehran Mehregany, *Case Western Reserve University, USA*
Mark G. Allen, *University of Pennsylvania, USA*

Plenary Speaker I

Session Chair: O. Brand, *Georgia Institute of Technology, USA*

- 8:15 am **MEMS AND MORE FOR THE BRAIN: THE CLUSTER OF EXCELLENCE *BRAINLINKS-BRAINTOOLS* AT THE UNIVERSITY OF FREIBURG 1**
Oliver Paul and P. Ruther
University of Freiburg - IMTEK, GERMANY

Session 1 - Biomedical & Cellular Devices

Session Chair: M. Noh, *Drexel University, USA*

- 9:05 am **DEVELOPMENT AND *IN VIVO* TESTING OF RECONFIGURABLE NEURAL PROBES FOR CHRONIC ELECTRICAL RECORDING 5**
A. Dighe¹, U.P. Froriep¹, M. Sunshine², A. Ievins², P. Anikeeva¹,
C. Moritz², and J. Voldman¹
¹*Massachusetts Institute of Technology, USA and*
²*University of Washington, USA*
- 9:25 am **POLYMERIC MICRO-GRIPPER FOR APPLYING MECHANICAL STIMULATION ON THREE-DIMENSIONAL CELL AGGREGATES 9**
Q. Wang, S. Zhao, J.K. Choi, X. He, and Y. Zhao
Ohio State University, USA
- 9:45 am **NANOARRAY-ENHANCED IMPLANTABLE INTRAOCULAR PRESSURE SENSOR WITH REMOTE OPTICAL READOUT 13**
J.O. Lee¹, K. Huang¹, T.-T. Nguyen², D. Sretavan², and H. Choo¹
¹*California Institute of Technology, USA and*
²*University of California, San Francisco, USA*

10:05 am **Break and Tabletop Exhibits**

Session 2 - Bioassays

Session Chair: D. Horsley, *University of California, Davis, USA*

10:30 am **MEMS DEVICE INTEGRATED WITH VERTICALLY ALIGNED CARBON NANOTUBES FOR VIRUS CAPTURE AND DETECTION** 17
Y.-T. Yeh, N. Perea-Lopez, Y. Tang, B.U. McKellar, R. Harouaka, H. Lu, M. Terrones, and S.-Y. Zheng
Pennsylvania State University, USA

10:50 am **MULTIPLEXED PROTEOMICS USING TWO ORDERS OF MAGNITUDE ENHANCED DIELECTROPHORESIS: A COMPREHENSIVE ELECTRICAL AND ELECTROTHERMAL DESIGN METHODOLOGY** 21
S. Emaminejad, M.T. Barako, R.W. Davis, R.W. Dutton, K.E. Goodson, and M. Javanmard
Stanford University, USA

11:10 am **MICROFLUIDIC BARCODE ASSAY FOR MULTIPLEXED CLINICAL DIAGNOSTICS** 24
R. Lin, A. Skandarajah, R.E. Gerver, D.A. Fletcher, and A.E. Herr
University of California, Berkeley, USA

11:30 am **Poster Preview Session 1**
Session Chair: H. Jerman, *Coherent, Inc., USA*

12:15 pm **Networking Lunch**

1:45 pm - **Poster Session 1 – Contributed and Late News**
4:45 pm Session Chairs: X.-A. Fu, *University of Louisville, USA* and S. Tadigadapa, *Pennsylvania State University, USA*
See page 26 for listing of posters for Session 1

4:45 pm **End of Day**

Tuesday, June 10

7:30 am **Breakfast**

Plenary Speaker II

Session Chair: M. Mehregany, *Case Western Reserve University, USA*

8:15 am **NEEDS AND OPPORTUNITIES FOR NANOTRIBOLOGY
IN MEMS AND NEMS 28**
Robert W. Carpick, G.E. Wabiszewski, and F. Streller
University of Pennsylvania, USA

Session 3 - Materials & Surfaces

Session Chair: M. Gaitan, *National Institute of Standards & Technology, USA*

9:05 am **SILICON MIGRATION OF THROUGH-HOLES IN SINGLE-
AND POLY-CRYSTALLINE SILICON MEMBRANES 32**
J. Stehle^{1,2}, V.A. Hong³, A. Feyh¹, G.J. O'Brien¹, G. Yama¹, O. Ambacher²,
B. Kim¹, and T.W. Kenny³
¹*Robert Bosch Research and Technology Center, USA,*
²*University of Freiburg, GERMANY, and* ³*Stanford University, USA*

9:25 am **IMAGE VALIDATION OF PARALLEL SCANNING TUNNELING
MICROSCOPY WITH A CMOS MEMS PROBE ARRAY 36**
Y. Zhang, Y. Tang, L.R. Carley, and G.K. Fedder
Carnegie Mellon University, USA

9:45 am **Break and Tabletop Exhibits**

Session 4 - Fabrication & Materials

Session Chair: F. Herrault, *HRL Laboratories, USA*

10:10 am **RETAINING HIGH AREAL IN-PLANE MAGNETIC ENERGY
DENSITY OVER LARGE MAGNETIC THICKNESS:
A PERMANENT MAGNETIC MICROLAMINATION
APPROACH BASED ON SEQUENTIAL MULTILAYER
ELECTROPLATING 40**
Y. Li¹, J. Kim², M. Kim², A. Armutlulu², and M.G. Allen¹
¹*University of Pennsylvania, USA and* ²*Georgia Institute of Technology, USA*

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| | ¹ Stanford University, USA, ² Robert Bosch RTC, USA, and ³ University of Freiburg, GERMANY | |

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| | ¹ University of California, Los Angeles, USA, ² University of California, Berkeley, USA, ³ Lawrence Berkeley National Lab, USA, ⁴ Johannes Gutenberg-Universität, Mainz, GERMANY, and ⁵ California NanoSystems Institute, USA | |

Session 5 - Magnetic Transducers

Session Chair: R. Candler, *University of California, Los Angeles, USA*

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| | ¹ University of California, Davis, USA and ² Stanford University, USA | |

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| | ¹ University of California, Los Angeles, USA and ² California NanoSystems Institute, USA | |

12:10 pm - **Networking Lunch**

1:40 pm

7:00 pm - **Tuesday Banquet**

10:00 pm *Tuesday Banquet sponsored in part by Freescale*

Wednesday, June 11

7:30 am Breakfast

Plenary Speaker III

Session Chair: M.G. Allen, *University of Pennsylvania, USA*

8:15 am **MEMS ENTREPRENEURIAL PERSPECTIVES 64**
Kurt Petersen
Band of Angels, USA

Session 6 - High-Q Resonators

Session Chair: M. Rais-Zadeh, *University of Michigan, USA*

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RESONATORS WITH OUT-OF-PLANE
ELECTROSTATIC TRANSDUCTION 68**
D. Senkal, M.J. Ahamed, S. Askari, and A.M. Shkel
University of California, Irvine, USA

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S. Wang, L.C. Popa, and D. Weinstein
Massachusetts Institute of Technology, USA

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FREQUENCY VIBRATORY MEMS DEMONSTRATING
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S.A. Zotov, B.R. Simon, G. Sharma, J. Han, I.P. Prikhodko,
A.A. Trusov, and A.M. Shkel
University of California, Irvine, USA

10:05 am **PHASE NOISE REDUCTION IN AN OSCILLATOR THROUGH
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D.A. Czaplewski¹, B.S. Strachan², S.W. Shaw², M.I. Dykman²,
and D. Lopez¹
¹Argonne National Laboratory, USA and ²Michigan State University, USA

10:25 am **Break and Tabletop Exhibits**

Session 7 - Resonant Systems

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University of California, Berkeley, USA
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University of Michigan, USA
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L.L. Li¹, E.L. Holthoff², L.A. Shaw¹, C.B. Burgner¹, and K.L. Turner¹
¹*University of California, Santa Barbara, USA and*
²*Army Research Laboratory, USA*
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A. Ramezany, M. Mahdavi, X. Guo, and S. Pourkamali
University of Texas, Dallas, USA
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Session Chair: M. Sheplak, *University of Florida, USA*
- 12:55 pm **Networking Lunch**
- 2:25 pm - **Poster Session 2 - Contributed and Late News**
5:25 pm Session Chairs: H. Johari-Galle, *InvenSense, USA* and
S. Rajaraman, *Axion Biosystems, USA*
See page 33 for listing of posters for Session 2
- 6:30 pm - **Poster Session 3 - Commercial & Open Posters**
8:00 pm Session Chairs: A. Fitzgerald, *AM Fitzgerald & Associates, USA* and
P. Loeppert, *Knowles Electronics, USA*
See page 38 for listing of posters for Session 3

8:00 pm - **Rump Session**

10:30 pm Session Chairs: M. Allen, *University of Pennsylvania, USA*

Arlan Andrews, Sr., Edward M. Lerner, Stephanie Osborn,
and Jerry Pournelle
SIGMA, The Science-Fiction Think Tank

Thursday, June 12

7:30 am **Breakfast**

Session 8 Late News Papers Oral

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E.J. Ng, Y. Yang, Y. Chen, and T.W. Kenny
Stanford University, USA

8:30 am **ETCH-A-SKETCH RESONATOR 101**
R. Wang¹, S.A. Bhawe¹, and K. Bhattacharjee²
¹*Cornell University, USA* and ²*RF Micro Devices, Inc., USA*

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RESONATORS WITH 1.2 MILLION Q AND
43 SECOND DECAY TIME CONSTANT 103**
J. Cho, T. Nagourney, A. Darvishian, B. Shiari, J.-K. Woo, and K. Najafi
University of Michigan, USA

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V. Foroutan¹, R. Majumdar¹, O. Mahdavi pour¹, S.P. Ward², and I. Paprotny¹
¹*University of Illinois at Chicago, USA* and
²*University of California, San Diego, USA*

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SUB-NANOMETER PORES IN MICROFABRICATED
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T. Humplik¹, R. Raj¹, S.C. Maroo¹, T. Laoui², and E.N. Wang¹
¹*Massachusetts Institute of Technology, USA* and
²*King Fahd University of Petroleum and Minerals, SAUDI ARABIA*

9:30 am **TEMPERATURE-COMPENSATED TETHERLESS BULK
ACOUSTIC PHONON TRAP FOR SELF-OVENIZED
OSCILLATORS 109**
R. Tabrizian, A. Norouzpour-Shirazi, and F. Ayazi
Georgia Institute of Technology, USA

9:45 am **Break and Tabletop Exhibits**

Session 9 - Lab Chip & Microfluidics

Session Chair: H. Kim, *University of Utah, USA*

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¹*Purdue University, USA*, ²*NASA Ames Research Center, USA*, ³*Santa Clara University, USA*, ⁴*University of Texas, Austin, USA*
- 10:30 am **A PAPER-BASED MICROBIAL SENSOR ARRAY FOR RAPID SCREENING OF ELECTRICITY-PRODUCING BACTERIA 115**
A. Fraiwan¹, C. Dai¹, D.J. Hassett², and S. Choi¹
¹*State University of New York, USA* and ²*University of Cincinnati, USA*
- 10:50 am **A JANUS-PAPER PDMS PLATFORM FOR LAB-ON-CHIP APPLICATIONS 119**
R. Rahimi¹, M. Ochoa¹, T. Parupudi¹, A. Donaldson³, M.R. Dokmeci², A. Khademhosseini², A. Ghaemmaghami³, and B. Ziaie¹
¹*Purdue University, USA*, ²*Harvard-MIT Health Sciences and Technology, USA*, and ³*University of Nottingham, UK*
- 11:10 am **BI-DIRECTIONAL SWITCHING OF MICRODROPLET ADHESION ON DOPED POLYPYRROLE MICROSTRUCTURES 123**
W. Xu, X. Li, A. Palumbo, C.-H. Choi, and E.-H. Yang
Stevens Institute of Technology, USA
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²*Massachusetts Institute of Technology, USA*
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- P3 LOW VOLTAGE PIEZOELECTRIC NEMS RELAYS FOR ULTRALOW POWER DIGITAL CIRCUITS 135**
U. Zaghloul^{1,2} and G. Piazza¹
¹*Carnegie Mellon University, USA and* ²*Electronics Research Institute, EGYPT*
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University of Michigan, USA

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¹*University of Utah, USA and* ²*Corning Incorporated, USA*

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| | ³ <i>Lawrence Livermore National Laboratory, USA</i> , and | |
| | ⁴ <i>Brigham and Women's Hospital, USA</i> | |

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 E. Whitley¹, T. Takemoto², and G. Fox³
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 D.E. Oliver¹ and H. Steger²
¹*Polytec, Inc., USA* and ²*Polytec, GmbH, GERMANY*
- OP2 A HIGH FREQUENCY, LARGE DISPLACEMENT UNDERWATER PHYSICAL ACTUATOR**
 D.J. Hoelzle¹, C.K. Chan², M.B. Scott², and A.C. Rowat²
¹*University of Notre Dame, USA* and
²*University of California, Los Angeles, USA*
- OP3 A MINIMALLY INVASIVE MEMS DRUG DELIVERY IMPLANT FOR THE TREATMENT OF PROSTATE CANCER**
 P. Zachkani¹, J.K. Jackson¹, F.N. Pirmoradi², H.M. Burt¹, and M. Chiao¹
¹*University of British Columbia, CANADA* and
²*University of California Berkeley, USA*
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¹*Boston University, USA* and ²*Boston University Medical Center, USA*
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 S. Dou¹, B.S. Strachan², S.W. Shaw², and J.S. Jensen¹
¹*Technical University of Denmark, DENMARK* and
²*Michigan State University, USA*

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¹*Michigan State University, USA and*
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¹*University of Florida, USA and* ²*Boeing, USA*
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¹*Georgia Institute of Technology, USA and* ²*KWJ Engineering, Inc., USA*
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¹*Boston University, USA and* ²*University of California, San Diego, USA*
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¹*University of Florida, USA and* ²*Boeing, USA*
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Cornell University, USA

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¹Georgia Institute of Technology, USA and ²University of Pennsylvania, USA
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University of California, Irvine, USA
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¹University of Maryland, College Park, USA and
²University of Maryland, Baltimore, USA
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¹University of California, Berkeley, USA and
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University of Illinois, Urbana-Champaign, USA
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University of Maryland, College Park, USA
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NOTES

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